THE DISCRETE DYNAMIC MODELS OF THE INTERACTION OF COMPLEX - COMPOSITE STRUCTURES WITH THE DYNAMIC LOADS

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1. Introduction

In the given paper the generalized formulation of the problem of computer modelling of the complex-composite structure interaction with different types of dynamic loads and effects is discussed.

The different variants of the joint and the space structure element modelling are suggested. It allows to consider the complex non-linear of the dynamic effects and modes of the joint bending-torsional oscillations (natural and forced) of such structures as bridges, towers, high-rise buildings, that are contacted with the complex non-uniform basis.

2.The Universal Computing Systems or Individual Programmes - what is to be Applied and When ?

Due to the experience of the usage and applicability analysis of the certain Universal Computing Systems (UCS) for the solution of some problems connected with the structural mechanics, the authors came to the conclusion that most of UCS aimed for the solution of rather limited number of problems on structure statics and dynamics (about lacks some UCS both necessity of application of individual models and approaches was spoken, for example, in articles [2-7]).

In this case the problems on the calculated scheme choice in the linear and determinated models for the systems with constant parameters are solved. (Non-linear oscillations, stochastic excistitions and the problems in the time and frequency regions are not discussed).

Also the linearization of the system with small non-linearity and small number of degrees of freedom according to one of the known variants is held. (Here such factors as the variability of the parameters or system structure, the complex character of the excistations with stops, etc. are not regarded).

Therefore, the quality of such mathematical guaranteeng as many of UCS is hardly possible to satisfy the users. Due to that, the popularization and development of the computer modelling methodology of the structure dynamics problems, aimed for the rapid making out of an individual algorithm and program for a separare problem, is of special importance.

Besides, one of the aims at the problem solution is the certain unification and standartization in the very approashes to the problem. This unification can be done beginning with the choice of the dynamic models, the working out of the motion differential equations, the consideration of all necessary complex qualities, phenomena and dynamic effects.

The quantification of the dynamic models of the complex-composite systems with the variable structure depending on the effect character and intensivity lue to the definite rules is rather convenient method used by the authors during 20 years at the investigation of the oscillations of buildings, bridges, towers, carriages, vibroplatforms and many other structures and environments.

In the suggested variant the complex mathematical apparatus isn't to be introduced as used in the Method of Finite Elements (MFE). But the precision of the received solutions can be compared with the results MFE. More than that, the definite advantage can be recived as for the quality and correctness of the investigated phenomena. Here the analysis is given as for the usage of some universal computing systems for the solution of such problems.

3. To the Methods of the of the Structure Discrete Dynamic Model Working Out

The problem of the correct working out of the object calculated scheme or dynamic model is one of the major and most important items during any structure calculation. Here different variants of the space structure joint and element modelling can be preliminary suggest and discussed.

The finally approved dynamic models should take into consideration, for example, complex modes of the bending-torsional oscillations, analyse the complex motions with resonance phenomena, the motions with stops and other non-standard effects.

For an example on Figure 1, a scheme of a carrying tower of a pipe of height 150 m, and on Figure 1, b - one of the forms (fifth) natural oscillations of this tower with three Dynamic Vibration Absorbers (DVA) is shown. On Figure 2 one of the forms of natural oscillations of a frame structure of height about 70 m is given.

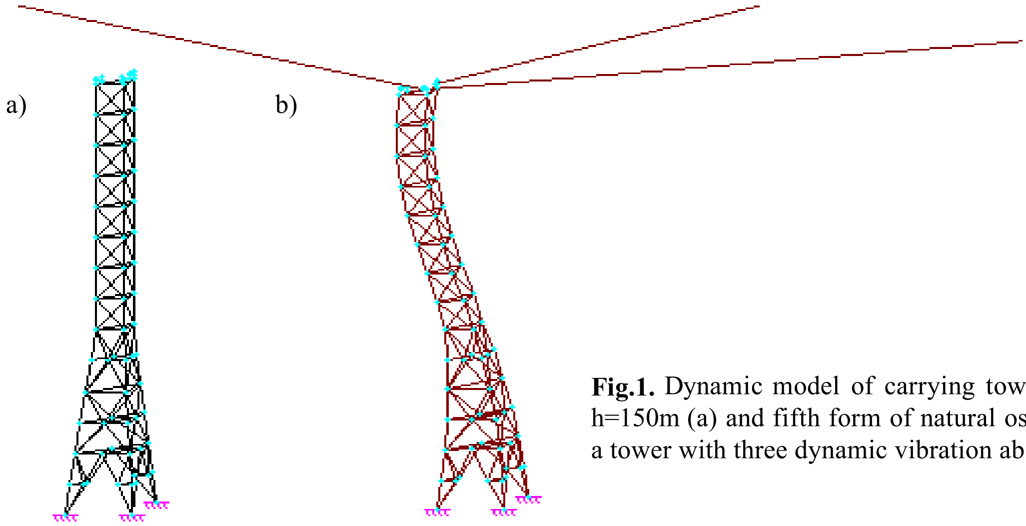

Fig.1. Dynamic model of carrying tower of a pipe h=150m (a) and fifth form of natural oscillations of a tower with three dynamic vibration absorbers (b).

To obtain the processes

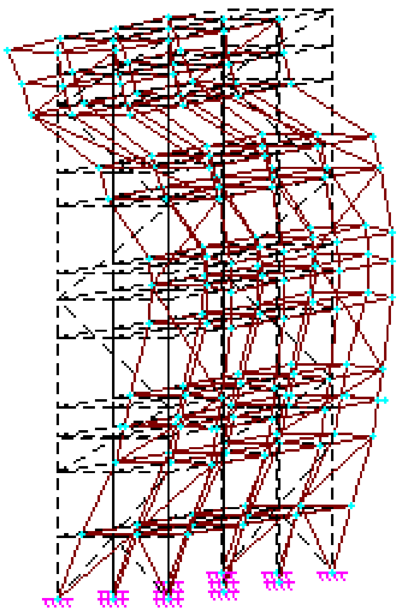

Fig.2. One of the forms of natural oscillations of a dynamic spatial model of a frame structure

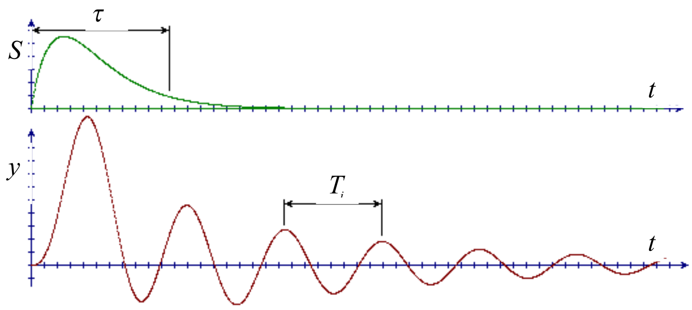

Fig.3. An impulse $S(t)$ with duration τ and reaction on it - displacement $y(t)$ of structure with period T_i for i form of natural oscillations

characteristic for the real object in the computer is possible only on conditions that the dynamic model doesn't regard so large number of degrees of freedom as considers the interaction of the whole system with the other external effects [4-6].

So, at action on object of external force of pulsing character (top curve on Figure 3, duration of a impulse τ) the reaction of a specific structure can represent its natural oscillations with one of mode frequencies (bottom curve). Their

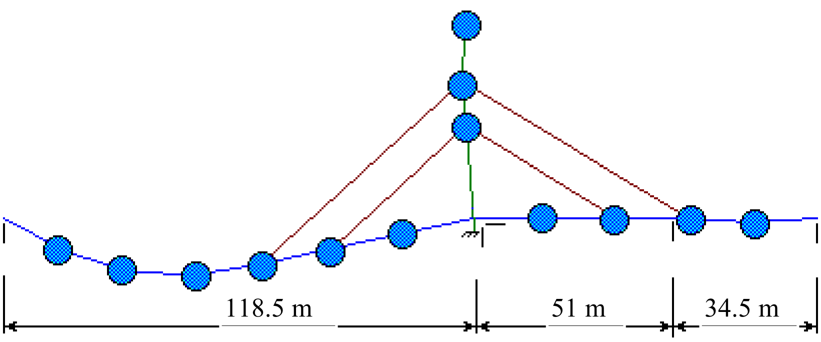

Fig.4. One of the forms of natural oscillations of dynamic model the cable-stayed bridge

period $T = k\tau$, thus factor k in the given example is near to 1.

For example, at the decision of a practical problem on stabilization of the cable-stayed bridge through the river Neris in Vilnius (Lithuania) application of plane dynamic model (Figure 4) did not allow to simulate the necessary natural and forced modes of bending-torsional vertical oscillations. Development of special spatial (three-dimensional) model, described in articles [3, 7], was required.

In some cases on a spatial structure (multi-storey building, the powerful base under the equipment) works of the kinematic influence natural or tethnic of an origin (natural, industrial or transport seismics; the example of a case of vibrations of a building, located in a zone industrial seismics, is shown on Figure 5). In such problems is it is necessary to take into account not only movement of the basis, but also non-uniform elastic, inertial and dissipative of properties of the ground basis on a large its extent (the model of such basis is offered in article [6]).

Our experience shows that the number of freedom and the determination of the generalized coordinates should be grounded during the choice of the type and branching (plane or space) of the model. In the most cases the analysis of the natural and forced oscillations not regarding the structure torsional displacements caused the serious errors in the natural frequency spectra, in the forced oscillation amplitude values, in the self-oscillations etc.

In the suggested methods the parameters and types of the inertial, rigid and dissipative characteristics can reflect the various qualities of the real object or its analog:

- the change of the object element mass in the process of oscillations, loading, unloading, etc;
- the change in time the rigidity and friction in the materials and joints at the rapid physical and chemical processes in the object or in the environment;
- non-linear qualities of the elastic forces in the structure elements;
- the other effects regarding their type, structure and major peculiarities.

In the paper examples of the analysis of dynamics of complex - compound structures are given. For this through special receptions of input in computer model real loads, for example, maintained object.

Certain return to application in computer models of analog devices and converters is at the moment planned. So, hybrid simulating engineering expediently to use in problems of parallel work of the digital computer with the measuring and recording equipment at natural dynamic tests, at modelling essential non-linear characteristics in units and systems.

4. The Peculiarities of the Modelling and Testing of Some Problems of the Objects Aerodynamics and the Interaction of the Frameworks Constructions with Shock and Movable Loads

4.1. Vortex inducement. In article [2] the diagram of increase in time of the vortex inducement self-oscillations of pipeline transition of the pipeline in a wind flow is shown. It is enough 2-th - 3-rd minutes of such interaction of a horizontal pipe (and in an example on Figure 1 - vertical pipe into of a tower) with a flow on critical speed, as vertical dynamic load on a pipe from a wind (without introduction of the stability measures) become comparable with loads from own weight and bring in destruction of object.

4.2. The Impact of a falling body and elastic of the Frameworks Constructions. For the correct decision of problems of interaction, for example, complex bridge (as of the cable-stayed, shown on Figure 4) or other object with shock or movable loads development of special methodics was required. These methodics should allow modelling of such problems at practically any kinds not only loads and their changes in time, but also adjacent subsystems and constructions (including the complex entry conditions, non-linear properties of the elastic-friction of units, zones of contact with layers of the grounds).

Figure 6 illustrates the decision of a test problem of elastic - viscous impact at free fall of the steel ball on a simple beam. Curves 1-3, describing changes in time are resulted: movings average section of a beam (1), mutual rapproachement it and ball (2), and also force of their interaction (3). Received through discretic model of a core (made from absolutely rigid cells the decision is similar to models of article [7]) comes nearer to the known decision S.P.Timoshenko for continuous of model [8] theme closer, than the greater quantity of cells has model: at 10 cells an error makes (for maximum of the beam displacements) 1,4% and at 20 cells - 0,2 %.

4.3. Movement (any by the form and mode) load on an elastic-deformed construction with possible break of connections between them. Testing a problem of interaction of an elastic construction with inertial concentrated movable load at unilateral character of connections between them we shall make on conditions and analytical decisions, for example, resulted V.B. Zaporogets [1]. As it is visible from the Table 1, the results for a design with an originally rectilinear axis ($g = 0$) differ not more, than on 9,8 % (for bending moment).

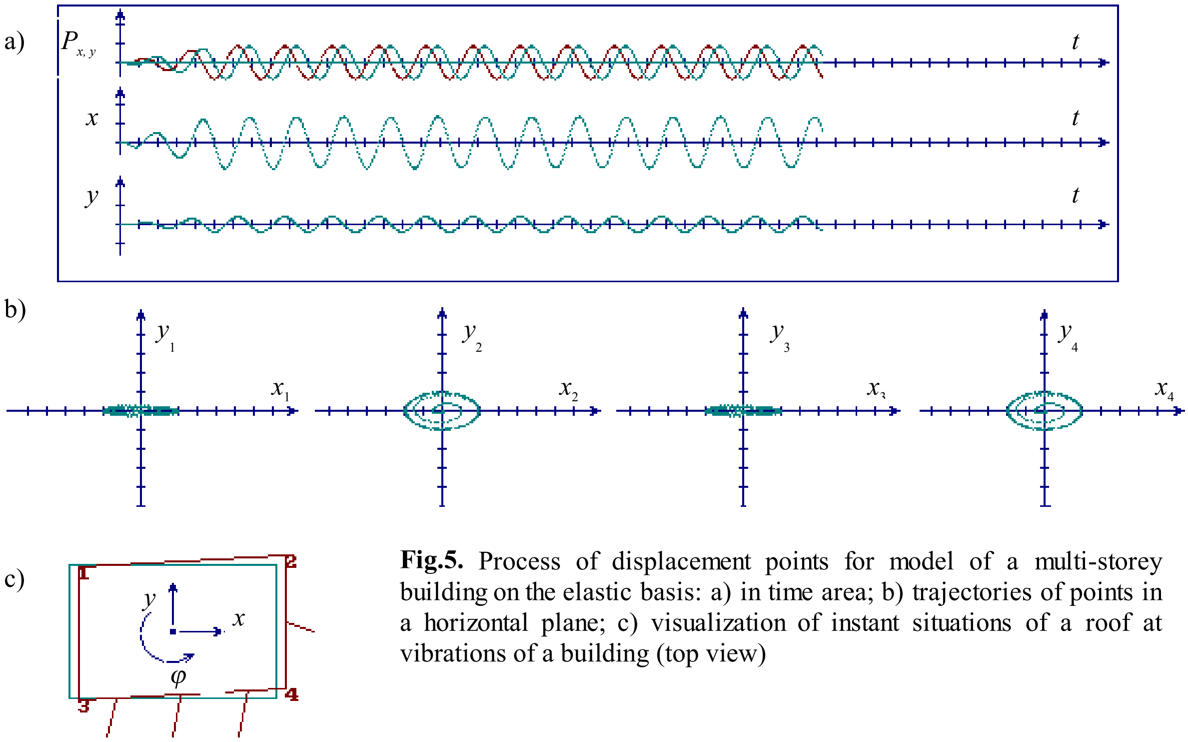

Fig.5. Process of displacement points for model of a multi-storey building on the elastic basis: a) in time area; b) trajectories of points in a horizontal plane; c) visualization of instant situations of a roof at vibrations of a building (top view)

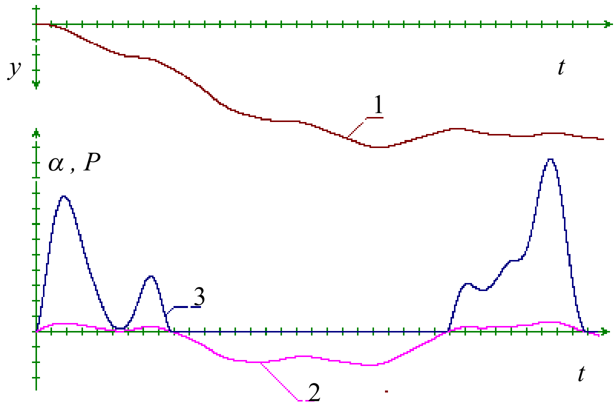

Fig.6. Processes at fall of a steel ball on a beam with elastic impact: 1- displacement average section of the beam; 2,3 - mutual rapproachement (2) and force of interaction (3) between the beam and the steel ball

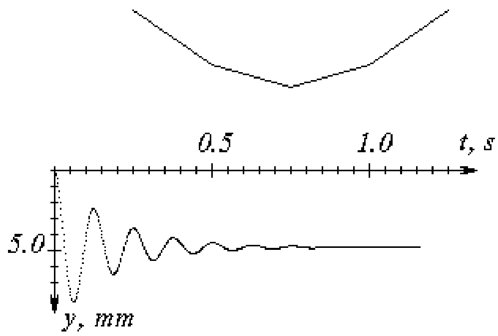

Fig.7. An example of testing of model on its free oscillations

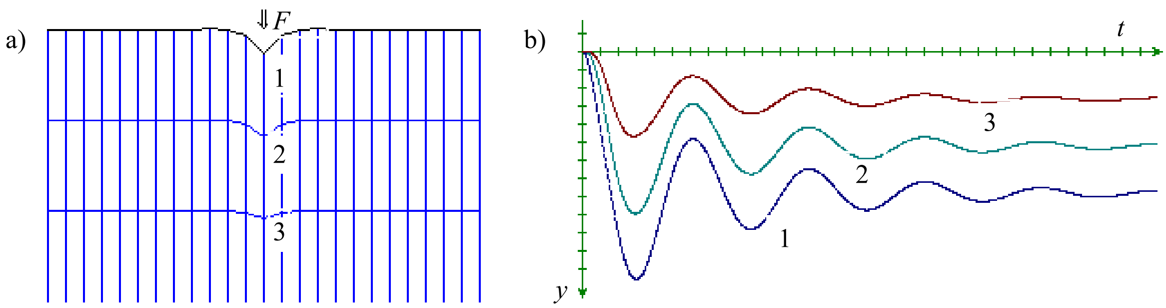

Fig.8. Oscillations of a beam on the multilayer elastic-dissipative basis: a) displacements of points 1, 2, 3 on "a vertical section " (plane model); b) vibrograms of these displacements

Table 1. The comarison of the obtained results with results of the article [1]

$m : M1$ = 1:1 α = 0.25		ω	η_1	M	η_1	Π	η_1	η
Method [1]	g = 0	1.598	0.605	1.562	0.635	1.790	0.678	0.906 -1.0
Proposal method	g = 0	1.578 (1.3%)	0.581	1.409 (9.8%)	0.570	1.744 (2.6%)	0.661	0.894 - 1.0
Proposal method	g = 9.81	1.441 (9.8%)	0.606	1.389 (11%)	0.565	2.375 (33%)	0.672	0.0175- 0.0464 0.897-1,0

In the Table 1 so relative designations are used: , η, η_1 - coordinates of the point of connections break and place of ball; Π- force; ω - vertical displacement; α - velocity; m, $M1$ - ball and beam masses. The account of an actual static deflection not only increases total displacements of a beam, but also give in a qualitatively other picture of complex "flight" of a load (at large speeds) with their interaction of shock character after it.

All problems of offered methodics are usually tested on free oscillations of systems - see Figure 7. The basis of structures if necessary of the correct account of their interaction is simulated through the special discretic system of cross elements [4, 6], allowing to study in common statics both dynamics of a structure and basis at any combinations of non-uniform layers ground (see Figure 8). For example, models, described above, allow at certain their updatings to decide many complex contact static and dynamic problems the mechanics:

- shift, coupling or break of layers of the basis, layered designs, base and ground - with variable (depending on a degree and direction mutual "press" of layers) forces of dry or other friction;
- inclined (to a surface, for example, of the airdrome plates of a covering) impacts and movement of complex bodies with braking and their elastic - plastic interaction with a construction and non-uniform basis (at unilateral or bilateral connections).

The suggested models found a wide use both at the design of new structures and the dynamic monitoring of the exploitated structures.

References

1. Zaporogets V.B. On Influence of Constraining Linkage Type on Strain- stress State of moving load-beam system. 2nd Polish-Ukrainian seminar " Teoretical Foundations in Civil Engineering ". Warsaw, june-july 1994. Dnepropetrovsk. June 1994, p. 146-150.

2. Kazakevitch M.I., Kulyabko V.V. Complex Study of Dynamics and Aerodynamics of the Long-Span Pipelines and Bridges. EAST EUROPEAN Conf. On Wind Engin. "EECWE-94". 4-8 July 1994. Warsaw, Poland. Prepr. Part 1. Vol. 2 (G-L), p. 113-122.

3. Kazakevich M.I., Kulyabko V.V. Stabilisation of a Cable-Stayed Footbridge. IABSE Symposium San-Francisco - 1995: " Extending the Lifespan of Structures ". Intern. Assoc. for Bridge and Structural Engineering. - San-Francisco (USA), 1995. - p. 1099 -1104.

4. Kulyabko V.V. Drawing up of the Dynamic Models of Long-span and High-rise Reinforce-concrete Buildings and Structures in the Time of the Diagnostics. Diagnosis of Concrete Structures. Proceedings of the 2nd RILEM (Intern. Union of Testing and Research Laboratories for Materials and Structures). Intern. Conf. Š trbskì pleso, Slovakia, Oct. 7th-11th, 1996, Bratislava, p. 382-385.

5. Kulyabko V.V. The Dynamic Methods of the Structure Operation Calculation, Testing, Diagnostics and Prognostication of the Working of Constructions and Structures. Materials of 2-th Intern. Symposium "Frakture Mechanics and Physics of Construction Materials and Structures", 1996, Lviv-Dubliany, Ukraine, p. 64-65.

6.Kulyabko V.V. Construction of the Same Type Models of Moving Transport Means, Way and Nearest Structures and Account of their Dynamic Interaction. In book "Problems the mechanics railway transport: Dynamics, reliability and safety of the rolling-stock" (9th Intern. Conf., May 1996). Dnepropetrovsk, 1996., p.95-96.

7. Kulyabko V.V., Dubihvost A.A., Chaban V.P., Golub D.V. The Usage of the Straight Line Method for the Solution of the Complex System and their Element Dynamics Problems. 3th Ukrainian-Polish seminar

"Teoretical Foundations in Civil Engineering". Dnepropetrovsk 24.06-02.07.1995 Warsaw, June. 1995, p. 97-104.

8. Timoshenko S.P. Zur Frage nach der Wirkung eines Stosses auf einen Balken. Zeitschrift für Mathematik und Physik, 1913, Bd. 62, Heft 2, SS. 198-209.